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FIRST ANNUAL REPORT
ON THE INFLUENCE OF PLANT DAMGE
FROM SIMULATED HAIL ON YIELD OF TOMATOES

BY

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FIRST ANNUAL REPORT ON THE INFLUENCE OF PLANT DAMAGE FROM SIMULATED HAIL AT VARIOUS STAGES OF PLANT DEVELOPMENT ON YIELD OF TOMATOES

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This was the first year of a proposed 3-year study. A considerable amount of work was done and much data gathered. However, as frequently occurs, some data had relevance to the objectives and some did not.

The objectives for this first season briefly were:
1) To develop data for classification of the stages of growth and development of processing tomatoes.
2) To determine the influence of plant defoliation and stand reduction at various developmental stages on final yield of processing tomatoes.
3) To determine the influence of simulated hail injury at various stages of plant development on yield of processing tomatoes.

Field plots were established at the OARDC Vegetable Crops Branch near Fremont in the major processing tomato production area of Ohio and at the main campus, Wooster. A total of 876 plots comprising approximately 25,500 plants were established and included transplanted and seeded plants, single and twin rows, up to 6 varieties and even some fresh market, staked tomato plots. A small preliminary study was also conducted in the greenhouse at Wooster. A total of $780.05 worth of crushed ice was used in the simulated hail plots. The hail machine was provided by the association and was extremely effective in simulating hail. These initial studies were very extensive and provided much data. Not all the data can be presented in this report. The pertinent data will be given, however.

Transplants for the studies were grown in Georgia and provided by the H. J. Heinz Company and the Campbell Soup Company. Seed for the field seeded trial was also obtained from H. J. Heinz. Cultural care was uniform for all experiments and in line with standard practices. Although the simulated hail caused considerable plant and fruit injury, no additional fungicide sprays were applied to compensate for this injury. The season was generally classed as good although there was a period of excessive rainfall in July; injury to plants in the plots was very little if any.

A brief description of each individual study follows:

A) Plant Development Study - Wooster. Transplants of 5 cultivars were planted on May 23, 1986 in rows 30 ft. long on 5 ft. centers with plants spaced 11 in. apart. Cultivars were Ohio 832, Heinz 1810, Easy Winner, Early Harvest and a hybrid Heinz 7151. On May 28, a fresh market cultivar, Sunny, was planted with plants spaced 18 in. apart. Sample plants were removed weekly starting 2 weeks after planting and development data recorded.

B) Simulated Hail - Transplants - Fremont. Transplants of H-1810 were planted on spring beds (sandy-loam soil) in 30 ft. x 5 ft. single rows with 11 in. plant spacing on May 9, May 26 and June 4, 1986. This planting sequence provided for plants of 3 different ages for the two simulated hail treatment dates. The hail machine and a gasoline-powered "weed wacker" were used to simulate hail injury. The weed wacker effectively removed leaves, stems and fruits (or flowers) but the plant injury did not resemble hail. The hail machine was very effective and the several experienced hail adjusters classed the injury as closely resembling actual hail. The hail treatments were made on June 24 and July 21. The weed wacker treatments were applied the following day in each case. Injury evaluations were made by several company hail adjusters usually either the same day or the day following injury. The criterion used was % defoliation. Injury level treatments are given in subsequent data tables.

As harvest maturity approached, the plots for each planting date were treated with 3 pts. per acre of Ethrel when the majority of the fruits were mature green on the check row plants. Only 3 replications were treated with the 4th rep being used to estimate the delay in maturity caused by the simulated hail injury treatments. Harvest was by machine and was done when the check plants were at optimum ripeness for harvest. Fruits were graded into ripes, greens and rots.

C) Simulated Hail - Fresh Market - Transplants - Fremont. Transplants of Sunny were obtained from a commercial grower and planted on May 6 and on May 30 in 5 ft. x 15 ft. rows with plants spaced 18 in. apart. The plants were staked and tied according to commercial practice. Further, cultural practices were according to good commercial practice. The stakes complicated the treatment application with the hail machine in that it could not move down the rows but the ice was blown down the rows from each end of each row to be treated; hence, the reason for only 15 ft. of row. The hail and weed wacker treatments were on the same dates as the previous experiment and injury evaluations were made also as above. The plants were harvested by hand several times with the fruit counted and weighed and graded as U.S. No. 1, U.S. No. 2 and culls; culls were further evaluated for reason(s) for the cull classification of each fruit. Precise treatments are given in subsequent tables.

D) Simulated Hail - Field Seeded - Fremont. Seed of H-1810 were planted on May 8, 1986 using a John Deere vegetable seeder which seeded 3-5 seeds spaced 9 in. apart. Rows were 30 ft. x 5 ft.

Vermiculite was placed in the seed furrow as an anti-crustant. Simulated hail treatments were made on June 26 and July 28, 1987. Cultural care and harvest were similar to the "B" study above. Specific treatments are in subsequent tables.

E) Leaf Removal by Hand - Fremont. Transplants of H-1810 and H-7151 were planted on May 12, 1986. Plots were bedded on 5 ft. centers and single rows 30 ft. x 5 ft. and twin rows of 30 ft. x 1.5 ft. between twin rows on the 5 ft. beds were planted with a precision planter. Plant spacings were 10 in. for single rows and 20 in. for twin rows to provide equal plant population. Cultural care and harvest was similar to the "B" study above. Leaves were removed by randomly clipping off leaves and/or leaflets with small plant clippers on June 2, June 16, July 2 and July 21, 1986. Treatments are given in subsequent tables.

RESULTS

A) Plant Development - Wooster.

The five cultivars of processing tomatoes had similar growth patterns although they were different in fruit maturation (Fig. 1-3). Some cultivars were more vegetatively vigorous than others and some were more upright in growth during the vegetative period. However, growth of the primary stem was similar in all cultivars and generally developed 4 fruiting clusters. Secondary short growth was also similar with side shoots developing 4 to 6 flowering clusters. The terminal flower clusters on the primary and secondary shoots developed at about the same time although the first and second clusters on the primary shoot developed considerably earlier; up to 2-3 weeks earlier. Generally the major fruit set for harvest comes from the second through fourth clusters on the primary stem and the first 3 or 4 clusters on the secondary shoots. Fruits on the first cluster of the primary shoot usually become over-ripe and rot before harvest. Many flowers on the terminal clusters do not set fruit. Thus, the so-called "full bloom" when the plants are at maximum flowering of the terminal clusters and the plants appear yellow with flowers from a distance, does not provide the majority of fruits for harvest. It is likely however, that many of these flowers will set if the set is minimal on the earlier clusters.

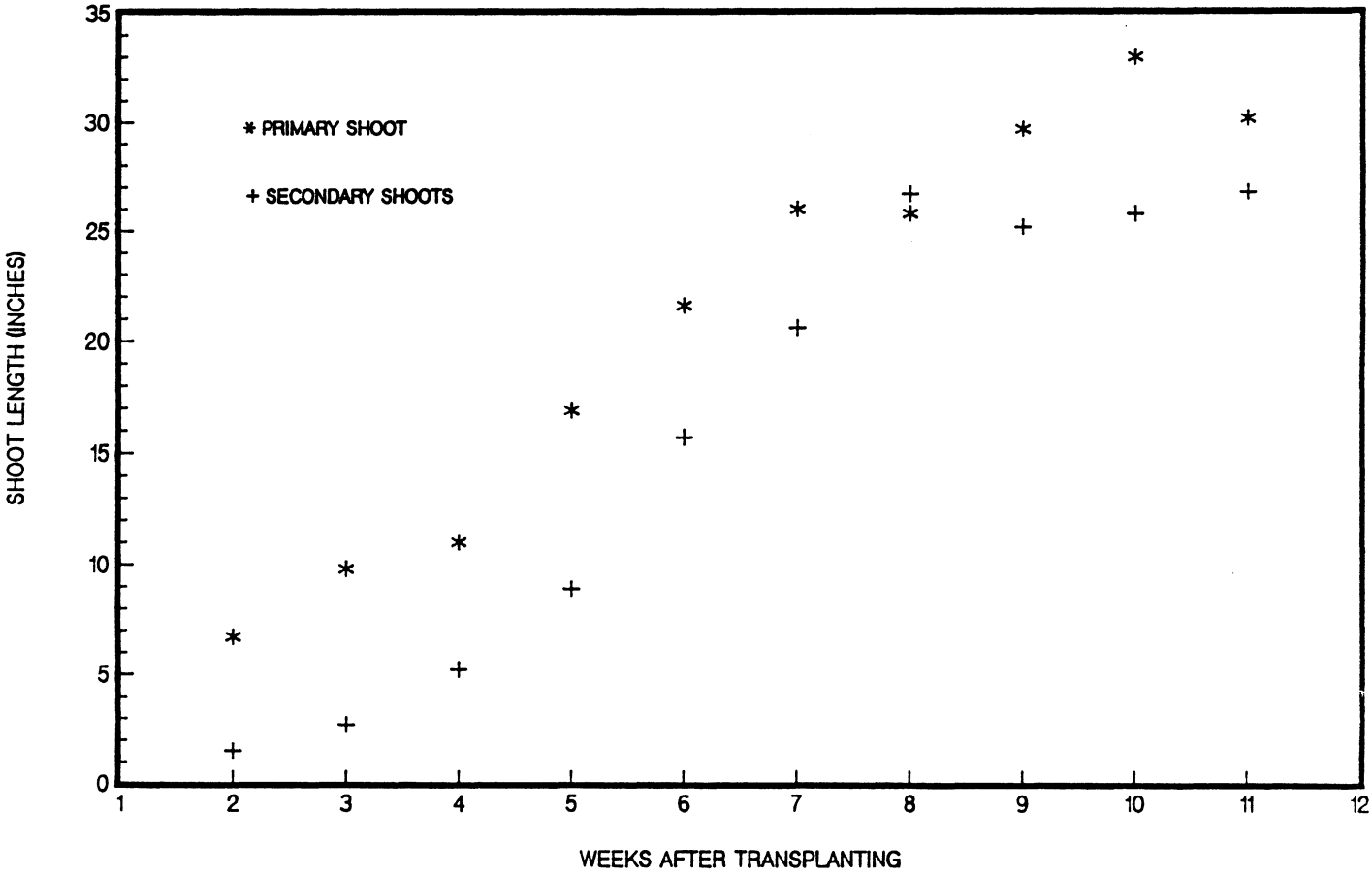

Fig. 1 – Plant growth and development of processing tomatoes – means of five cultivars

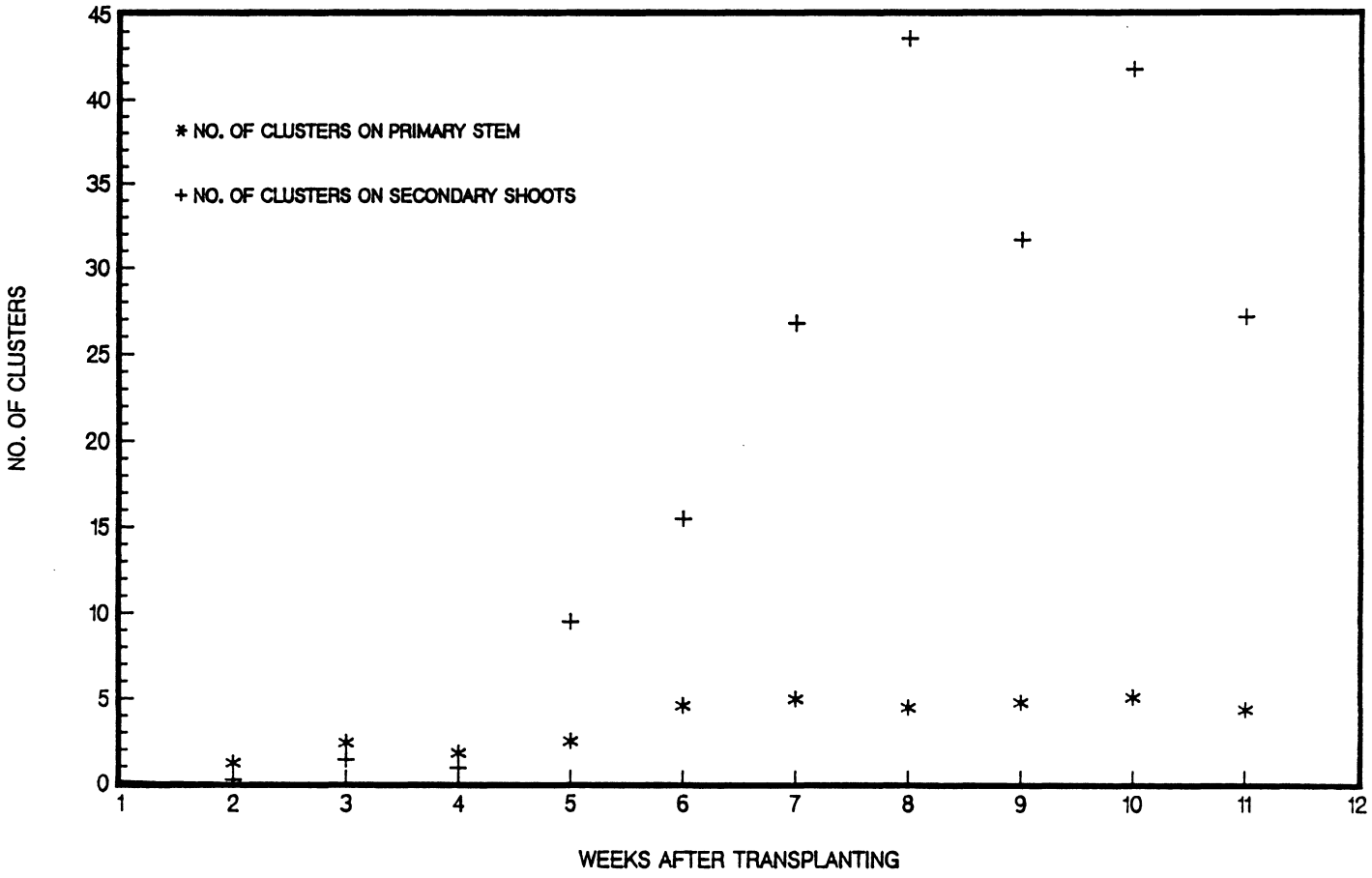

Fig. 2 – Development of flowering/fruiting clusters on primary stem and secondary shoots of processing tomatoes – means of 5 cultivars

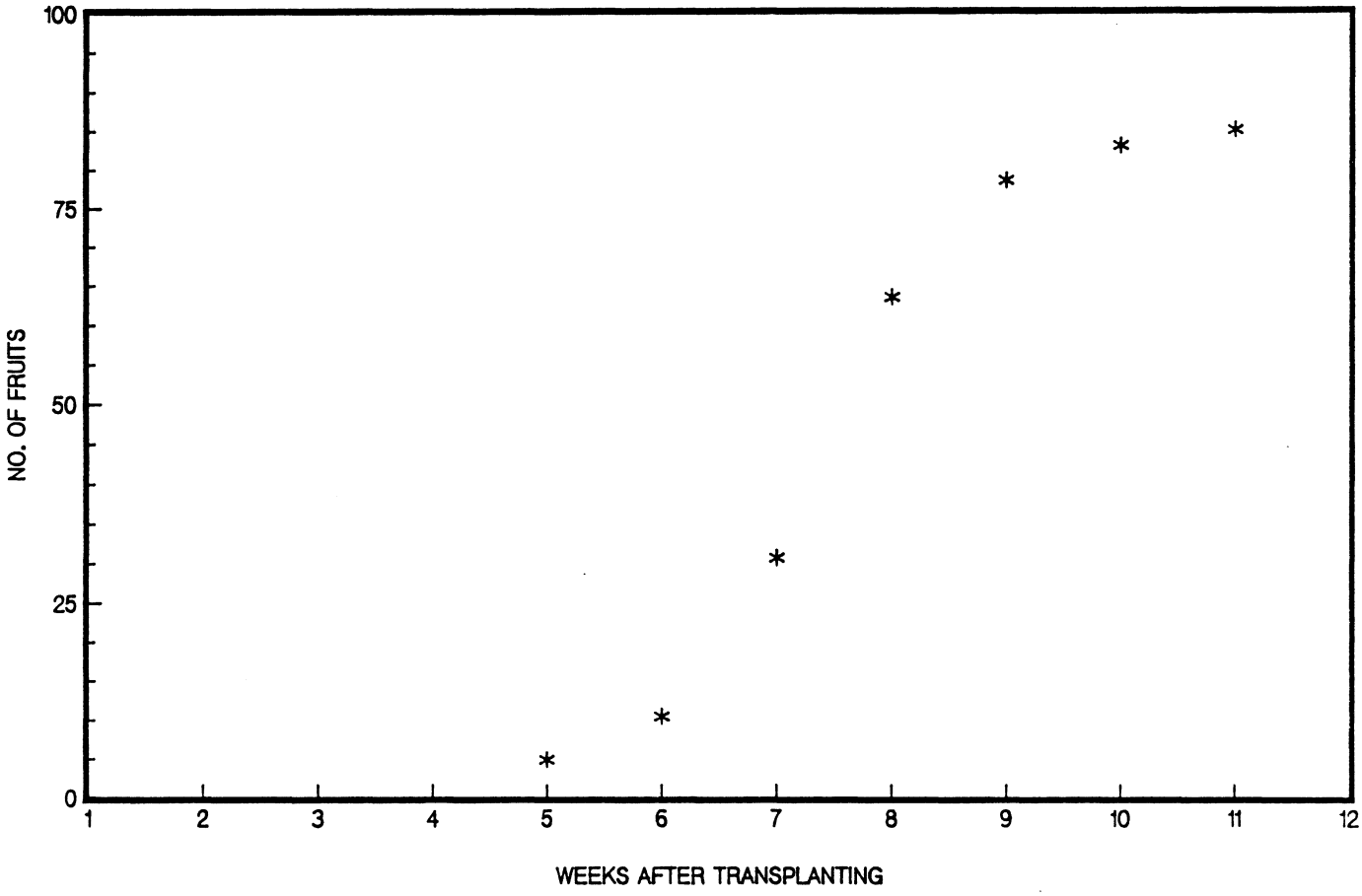

Fig. 3 – Development of fruits on processing tomatoes – means of 5 cultivars

Transplants appear to go thru an early period of vegetative growth that lasts from 6 to 8 weeks followed by a period of dramatic fruit growth (yield accumulation), then by fruit ripening or ripe fruit accumulation. The heavy bloom for harvest period usually occurs 5 to 6 weeks after planting but is affected by cultivar, earlier cultivars bloom earlier and later ones as much as 2 weeks later. However, the length of fruit growth and development also varies for early and late cultivars and the primary bloom period may not be greatly different between early and main season cultivars. The bloom period generally lasts for about 3 weeks depending upon growing conditions, especially temperature and rainfall. Fruit ripening for once-over mechanical harvest usually occurs over about a 3-week period although it will vary depending upon concentration of fruit setting, temperature, and use of Ethrel.

The fresh market cultivar "Sunny", is a late cultivar and it has a fairly long vegetative period although it is semi-determinant. It was about 6 weeks after planting before flowers on the first cluster appeared. This was followed by a fairly steady sequence of flowering on the primary stem up to 5-6 clusters. Secondary shoots also bloomed and later set fruits. The developmental stages appear to be similar to those already in use by insurance adjusters.

B) Simulated Hail - Transplants - Fremont.

Teams of adjusters rated the defoliation from the hail and weed wacker injury and established the stages of development from the treatments. The defoliation ratings are given in Table 1. These data indicate that the hail machine was quite effective in defoliating the plants and a range from slight to severe injury occurred. The weed wacker was very effective in removing leaves, whole shoots and fruits but the injury did not resemble hail injury and it will likely not be used in future studies.

Table 1. Defoliation of Tomato Transplants From Simulated Hail or Weed Wacker (w/w) Based Upon Estimates of Experienced Adjusters.

	Defoliation Estimates by Adjusters (%)					
	Treated 6-24			Treated 7-21		
Treatment Planted=	5-9	5-24	6-4	5-9	5-24	6-4
Control	0	0	0	0	0	0
Slight Hail	38	32	41	29	23	19
Moderate Hail	56	63	48	44	47	38
Severe Hail	85	93	94	67	68	57
Slight w/w	30	28	27	28	25	25
Moderate w/w	45	45	39	49	49	43
Severe w/w	75	78	77	88	80	84

Staging data given by the adjusters indicates that the 3 planting dates gave a relatively wide range of stages from 4.0 to 7.0 for the first treatment date (June 24) and 7.5 to 10.0 on the second date (July 21).

The May 9 planting (Planting No. 1) was judged to be at Stage 7 on the June 24 hail treatments--mostly flowered; 10 fruits or less. Additional description of the plant development: the first cluster on the primary stem had fruits up to about half of final size, a few second clusters had a few very small fruits developing and the remaining flowers were in full bloom, the third and fourth flower clusters on the primary stem were in full bloom; some first cluster flowers on secondary shoots were set and a few had very small fruits present, the second clusters on the secondary shoots were in bloom; flower clusters were showing on the terminals of the secondary shoots but no flowers were open. Experience suggests that all the flowers that will set the crop were either set or in bloom. The terminal flowers usually do not set fruits if most of the earlier flowers have set fruits.

The May 26 planting was judged to be at Stage 6.5 on the June 24 treatment date--first fruits set, mostly in flower. Additional description of the plant development: the first and second clusters on the primary stem had fruits up to about one-fourth final size, a few third cluster flowers were set and fourth cluster flowers were in bloom; a few first cluster flowers were open on secondary shoots and second and third clusters were visible but not in bloom.

The June 4 planting was judged to be at Stage 4 on the June 24 treatment date--first terminal flowers in bloom. Additional examination indicated that a few first cluster flowers on the primary

stem were open, second and third cluster flowers on the primary stem and first cluster flowers on secondary shoots were visible but not open.

The May 9 planting was judged to be at Stage 10 on the July 21 treatment date--fruit beginning to show color. Additional comments: post-fruit set, fruit growth period, plants opened up or broken down from fruit weight, one or two fruits per plant starting to show red color.

The May 26 planting was judged to be at Stage 8.5 on the July 21 treatment date--flowering top, fruits present on lower clusters. Additional comments: majority of fruits were set although many open flowers were present on the terminal clusters (these likely did not set fruits). Some persons classify this stage as "full bloom" on the determinant plant types of processing tomatoes. There were a few ripe fruits on the first clusters of a few scattered plants.

The June 4 planting was judged to be at Stage 7.5 on the July 21 treatment date--flowers top, fruit lower and green. Additional description: should be classed as full bloom, fruits set on the earliest clusters were up to about 1 inch diam., a few fruits near full size on earliest clusters, most fruits less than half of final size.

Yield data are presented in Tables 2 and 3. Some responses to injury appear obvious; 1--Any injury resulted in reduced yields of ripe fruits and the greater the injury the greater the yield reduction. 2--Injury resulted in a delay in maturity, and generally, the earlier the injury in plant development the greater the delay and the greater the injury the greater the delay. 3--The loss in yield was real because the total yields of ripes plus greens and rots from treated plants was less than total yields from check plants, especially the severely injured plants. 4--The amount of rotted fruits was greatly increased on plants that had many fruits present at time of injury (treatment).

No correlations were run from this first season's data. It is felt that at least 2 seasons results are needed to obtain meaningful correlations between for example, defoliation severity and yield reduction.

There was no doubt that the hail treatments made before and during fruit set, caused a delay in maturity. Efforts were made to determine the precise delay but these data were lost due to heavy rains late in the season and an excessive work load of the field crew at the Vegetable Crops Branch to get as many other research efforts harvested as possible. It appears however, that the harvest maturity was delayed for several weeks and the severe hail treatment had the greatest effect on maturity. This maturity aspect could be a serious

consideration on injury evaluation because severe injury could delay ripening sufficiently to preclude harvest due to frost or early fall rainfall. The other factor relates to split-set on less severe hail treated plants. This aspect needs much further study.

Table 2. Influence of Plant Injury From Simulated Hail or Weed Wacker (w/w/) on Yield of Processing Tomatoes: cv. Heinz 1810, Fremont

Yield - Tons/Acre Ripe

Treatment	Planted=	Treated 6-24 5-9[a]	5-26[b]	6-4[c]	Treated 7-21 5-9[d]	5-26[e]	6-4[f]
Check		29.2	35.5	39.7	24.8	38.2	45.1
Slight hail		19.5	29.1	32.0	23.1	23.8	31.5
Moderate hail		17.0	26.3	34.9	23.1	15.7	22.7
Severe hail		4.9	11.8	14.0	11.9	5.8	9.1
Slight w/w		27.3	34.8	36.5	27.3	29.1	31.8
Moderate w/w		22.2	31.5	39.3	28.3	16.2	19.4
Severe w/w		8.9	22.8	29.1	12.0	6.5	2.3
LSD - 5%				6.3			

Yield - Ton/Acre Green

Treatment	Planted	Treated 6-24 5-9	5-26	6-4	Treated 7-21 5-9	5-26	6-4
Check		3.1	2.9	6.9	3.0	2.2	6.8
Slight hail		3.6	4.8	11.6	2.1	1.7	6.6
Moderate hail		5.7	10.1	13.3	2.0	1.0	6.7
Severe hail		5.9	17.4	17.7	0.5	1.1	9.6
Slight w/w		3.9	3.8	7.9	1.8	1.6	5.8
Moderate w/w		2.9	6.3	8.7	4.0	1.3	10.3
Severe w/w		6.9	12.2	15.6	0.5	1.4	8.4
LSD - 5%				2.9			

Yield - Ton/Acre Rots

Treatment	Planted =	Treated 6-24 5-9	5-26	6-4	Treated 7-21 5-9	5-26	6-4
Check		1.5	6.1	4.1	1.9	5.4	3.5
Slight hail		1.8	4.8	1.5	6.1	9.7	3.8
Moderate hail		2.1	2.7	1.3	4.3	10.9	4.0
Severe hail		1.0	0.7	0.2	8.4	9.0	2.9
Slight w/w		1.7	5.1	2.7	3.5	7.1	4.4
Moderate w/w		2.3	4.5	1.8	3.5	7.7	3.9
Severe w/w		1.8	2.0	0.9	5.9	6.6	1.0
LSD - 5%				1.7			

[a]Stage 7 when treated; [b]Stage 6.5 when treated; [c]Stage 4 when treated; [d]Stage 10 when treated; [e]Stage 8.5 when treated; [f]Stage 7.5 when treated.

Table 3. Influence of Plant Injury From Simulated Hail or Weed Wacker on Yield (%) of Ripes, Greens and Rotted Fruits. cv. H-1810, Fremont

Yield - % Ripe

Treatment	Planted =	Treated 6-24 5-9	5-26	6-4	Treated 7-21 5-9	5-26	6-4
Check		85.3	79.2	78.4	83.4	83.0	81.2
Slight hail		78.0	75.0	70.7	73.5	67.3	75.2
Moderate hail		67.4	67.6	70.5	77.4	56.3	67.8
Severe hail		40.0	39.8	43.9	56.9	36.0	42.0
Slight w/w		82.9	79.0	77.2	82.9	77.0	75.7
Moderate w/w		80.5	74.0	78.5	80.1	63.5	57.0
Severe w/w		51.4	60.3	63.7	65.0	44.5	20.3
LSD - 5%				9.2			

Yield - % Green

Treatment	Planted =	Treated 6-24 5-9	5-26	6-4	Treated 7-21 5-9	5-26	6-4
Check		9.9	6.7	13.4	10.0	4.9	12.4
Slight hail		14.4	12.5	26.0	6.4	4.9	15.7
Moderate hail		23.7	25.4	26.8	6.6	3.6	20.2
Severe hail		51.4	57.6	55.3	2.6	7.1	44.5
Slight w/w		11.8	9.0	17.0	5.2	4.2	13.7
Moderate w/w		11.1	15.0	17.8	10.1	5.2	31.5
Severe w/w		38.2	34.2	34.4	3.0	9.8	70.8
LSD - 5%				7.9			

Yield - % Rots

Treatment	Planted =	Treated 6-24 5-9	5-26	6-4	Treated 7-21 5-9	5-26	6-4
Check		4.7	14.1	8.2	6.6	12.1	6.4
Slight hail		7.5	12.4	3.3	20.0	27.8	9.0
Moderate hail		8.9	6.9	2.7	16.0	40.1	12.0
Severe hail		8.6	2.5	0.8	40.5	56.8	13.5
Slight w/w		5.3	12.0	5.7	11.8	18.8	10.6
Moderate w/w		8.3	11.0	3.6	9.8	31.3	11.5
Severe w/w		10.2	5.5	1.9	32.0	45.7	8.8
LSD - 5%				6.4			

C. Simulated Hail - Fresh Market, Transplants, Fremont.

The same teams of adjusters evaluated the injury based upon % defoliation on the fresh market, staked tomatoes, as was done on the processing tomatoes (Table 4). Results indicate that a good range of defoliation occurred from the simulated hail but generally less so from the weed wacker (w/w). Further, the younger plants were easier to develop the range of injury than on the older plants. It was more difficult to get good penetration of the canopy thru the stakes and vines from the ends of the rows of the larger plants. The weed wacker was especially ineffective because of the stakes and strings used to support the plants which greatly interferred with the cutter.

Table 4. Ratings of Plant Defoliation by Adjusters on Fresh Market Tomatoes cv. Sunny, Fremont

		% Defoliation			
		Treated 6-24		Treated 7-21	
Treatment	Planted =	5-6[a]	5-26[b]	5-6[c]	5-26[d]
Control		0	0	0	0
Slight hail		18	15	20	25
Moderate hail		34	36	36	41
Severe hail		72	93	69	63
Slight w/w		23	13	12	16
Moderate w/w		27	27	19	15
Severe w/w		37	66	33	35

[a]Stage 5.5; [b]Stage 4; [c]Stage 9; [d]Stage 7.5

Staging done by the adjusters indicated a range from 4 to 9. It appears that this staging fits well with the descriptions in the handbook used by the adjusters. Plants of the May 6 planting were at Stage 5.5 on the June 24 treatment date and at Stage 9 on the July 21 treatment date. The May 30 planting was at Stage 4 on the June 24 treatment date and Stage 7.5 on the July 21 treatment date.

Yield data from the 2 planting dates were analyzed separately because there were 5 harvests for planting 1 and 2 for planting 2. There is little doubt that the hail injury caused reduced yields and reduced grade of fruits (Tables 5-10). Although there were some general yield reductions from the hail and weed wacker treatments the most serious effects were on pack-out of U.S. No. 1 grade fruits as the severity of hail increased. Also plants with more fruits present when treated had less No. 1 fruits. The most significant reason for culls were scarred and rotted fruits, generally caused by the hail and weed wacker treatments.

Table 5. Influence of Injury From Simulated Hail and Weed Wacker on Yield of Fresh Market Tomatoes, cv. Sunny, Fremont, Planted 5-6-86

Yield - Tons/Acre - Total of 5 Harvests

	Treated 6-24				Treated 7-21			
Treatment	No.1	No.2	Culls	Total	No.1	No.2	Culls	Total
Control	10.4	18.2	11.3	39.8	10.5	15.3	10.1	35.9
Slight hail	8.3	13.3	9.1	30.6	7.6	15.0	16.3	38.8
Moderate hail	5.6	15.9	11.1	32.6	3.8	9.6	18.7	32.1
Severe hail	3.4	6.8	5.8	15.9	3.8	8.0	22.0	33.8
Slight w/w	6.8	13.7	9.4	29.9	10.3	16.9	9.8	37.0
Moderate w/w	6.6	12.3	9.8	28.7	6.3	17.9	8.9	33.1
Severe w/w	6.1	13.7	8.3	28.1	11.5	17.8	10.5	39.6
LSD - 5%	4.5	6.0	3.9	7.9	4.5	6.1	3.9	7.9

Table 6. Influence of Injury From Simulated Hail and Weed Wacker on Pack-Out of Fresh Market Tomatoes, cv. Sunny, Fremont, Planted 5-6-86

	Treated 6-24			Treated 7-21		
Treatment	No.1(%)	No.2(%)	Culls(%)	No.1(%)	No.2(%)	Culls(%)
Control	23.7	43.7	32.6	28.6	38.7	32.7
Slight hail	23.8	44.0	32.2	19.8	32.9	47.3
Moderate hail	16.8	49.4	33.7	8.2	27.5	64.3
Severe hail	18.6	44.8	36.5	8.8	26.2	65.0
Slight w/w	26.1	43.7	30.2	22.6	45.3	32.1
Moderate w/w	25.9	38.9	35.1	16.9	43.2	33.2
Severe w/w	22.3	47.7	30.0	26.2	41.1	32.6
LSD - 5%	10.5	13.6	9.8	10.5	13.6	9.8

Table 7. Influence of Injury From Simulated Hail and Weed Wacker on Scars and Rots of Fruits of Fresh Market Tomatoes, cv. Sunny, Fremont, Planted 5-6-86

Scars - %

	Treated 6-24					Treated 7-21				
Treatment Harvest=	8-8	8-11	8-14	8-21	8-27	8-8	8-11	8-14	8-21	8-27
Control	5.0	21.5	2.1	16.6	4.1	0.0	4.4	22.0	16.9	2.6
Slight hail	8.3	10.1	13.9	4.2	2.3	51.4	53.8	36.1	53.5	34.1
Moderate hail	1.7	8.9	0.0	2.0	10.8	66.4	40.1	61.6	71.9	46.0
Severe hail	3.7	42.4	0.0	24.5	3.3	56.6	59.2	81.0	77.1	68.0
Slight w/w	7.7	0.0	7.2	19.6	8.3	32.4	10.5	14.7	5.4	5.3
Moderate w/w	17.4	14.4	5.3	15.0	2.5	11.7	18.2	3.8	8.3	3.6
Severe w/w	2.5	12.1	3.3	0.0	3.1	41.3	18.7	18.6	11.7	2.0
LSD - 5%					27.6					

Rots - %

	Treated 6-24					Treated 7-21				
Treatment Harvest=	8-8	8-11	8-14	8-21	8-27	8-8	8-11	8-14	8-21	8-27
Control	14.7	12.3	0.0	8.2	3.4	23.1	8.4	1.1	6.8	0.6
Slight hail	25.6	18.8	2.8	4.6	0.7	9.8	2.6	0.0	4.5	1.4
Moderate hail	24.2	13.7	16.7	2.0	2.4	9.4	3.5	0.0	0.6	1.8
Severe hail	35.7	5.5	7.3	27.3	5.5	19.6	0.0	2.2	6.7	2.4
Slight w/w	18.8	13.4	1.4	6.7	0.6	14.2	7.1	14.3	4.2	2.0
Moderate w/w	17.2	8.8	0.0	12.8	3.3	8.5	3.7	9.5	2.3	1.8
Severe w/w	18.4	12.2	1.7	2.8	3.6	13.6	5.3	3.4	7.9	6.8
LSD - 5%					14.9					

Table 8. Influence of Injury From Simulated Hail and Weed Wacker on Yield of Fresh Market Tomatoes, cv. Sunny, Fremont, Planted 5-30-86

Yield Tons/Acre - Total 5 Harvests

	Treated 6-24				Treated 7-21			
Treatment	No.1	No.2	Culls	Total	No.1	No.2	Culls	Total
Control	20.9	20.4	9.5	50.7	18.4	22.1	8.8	49.3
Slight hail	15.1	18.5	9.7	43.3	16.2	13.8	8.7	38.7
Moderate hail	18.5	18.5	7.6	44.6	8.5	10.0	16.7	35.3
Severe hail	16.8	15.3	6.7	38.8	9.1	8.3	10.8	28.1
Slight w/w	15.9	18.8	7.1	41.8	20.0	14.9	9.2	44.1
Moderate w/w	19.2	15.2	8.3	42.7	20.8	16.2	8.4	45.4
Severe w/w	17.5	18.8	4.9	41.2	18.7	15.2	7.3	41.1
LSD - 5%	7.0	6.8	3.9	9.3	7.1	6.8	3.9	9.3

Table 9. Influence of Injury From Simulated Hail and Weed Wacker on Pack-Out of Fresh Market tomatoes, cv. Sunny, Fremont, Planted 5-30-86

	Treated 6-24			Treated 7-21		
Treatment	No.1(%)	No.2(%)	Culls(%)	No.1(%)	No.2(%)	Culls(%)
Control	43.2	38.6	18.2	33.8	46.4	19.7
Slight hail	25.5	45.9	28.5	33.4	32.5	34.0
Moderate hail	29.2	50.3	20.4	18.0	28.7	53.3
Severe hail	32.7	36.6	19.5	23.3	28.8	47.9
Slight w/w	37.3	42.7	19.9	32.0	40.1	27.9
Moderate w/w	31.3	42.5	26.2	33.5	43.6	22.8
Severe w/w	32.8	52.6	14.6	33.0	45.4	21.5
LSD - 5%	14.9	13.8	11.1	14.9	13.8	11.1

Table 10. Influence of Injury From Simulated Hail and Weed Wacker on Scars and Rots of Fruits of Fresh Market Tomatoes, cv. Sunny, Fremont, Planted 5-30-86

Scars - %

	Treated 6-24		Treated 7-21	
Treatment Harvest=	8-27	9-4	8-27	9-4
Control	21.4	0.0	0.0	1.7
Slight hail	0.0	0.0	65.5	2.8
Moderate hail	0.0	0.0	81.5	21.0
Severe hail	0.0	0.0	81.2	25.4
Slight w/w	0.0	0.0	0.0	0.0
Moderate w/w	0.0	0.0	6.7	0.0
Severe w/w	0.0	0.0	19.0	1.5
LSD - 5%			17.6	

Rots - %

	Treated 6-24		Treated 7-21	
Treatment Harvest =	8-27	9-4	8-27	9-4
Control	11.1	0.0	17.3	1.2
Slight hail	6.5	7.7	2.4	8.6
Moderate hail	19.4	8.3	3.6	4.5
Severe hail	0.0	16.7	8.6	13.1
Slight w/w	0.0	0.0	4.8	0.0
Moderate w/w	0.0	5.5	6.7	0.0
Severe w/w	0.0	0.0	11.4	3.0

D. Simulated Hail - Direct Seeded Processing Tomatoes - Fremont.

This experiment was imposed on another experiment after the favorable experience with the hail machine. Because of this, the plants from the first treatment (June 26) were not evaluated for defoliation by the teams of adjusters. Observations suggested a reasonably good range from near 75% defoliation for the severe hail to about 40% for moderate hail to near 20% for slight hail. Defoliation ratings for the July 28 hail treatments averaged 48.1 from severe hail, 30% from moderate hail and 15.6% from the slight hail treatments.

The direct seeded plants were much more difficult to defoliate with the hail machine because the plants were much taller and more whippy and tended to give and flatten out when the air stream with the crushed ice hit them as opposed to the transplants which were shorter and stockier plants. Also the seeded plants were very large and difficult to walk through on the July 28 treatment date and it would have required an excessive amount of crushed ice to cause higher levels of injury.

Yield results (Table 11) indicate that the earliest treatments, June 26, did not significantly affect ripe fruit yields from a once-over mechanical harvest. There was certainly a trend towards lower ripe fruit yields and higher green fruit yields. This suggests a delay in development and fruit maturity from the more severe hail injury on plants that are just starting to flower (10-25% of first clusters with one or more open flowers). The later treatment (July 28) resulted in reduced yields which also increased as severity of injury increased. Plants on this date had the majority of fruits set and fruits were from "pea size" to 3/4 of final fruit size. Fruit rots were also increased from the hail treatments at this stage.

Table 11. Influence of Simulated Hail on Yield of Direct Seeded Processing Tomatoes, cv. H-1810, Fremont.

	Treated 6-26						Treated 7-28					
	Ripe		Green		Rots		Ripe		Green		Rots	
Treatment	T/A	%	T/A	%	T/A	%	T/A	%	T/A	%	T/A	%
Check	37.3	77	6.4	13	4.9	10	37.6	79	6.1	13	3.9	8
Slight hail	40.7	77	8.1	15	4.1	8	24.7	66	4.8	13	7.6	21
Moderate hail	35.3	74	9.9	21	2.5	5	21.1	62	7.4	21	5.3	17
Severe hail	34.2	73	10.7	23	1.8	4	18.4	60	4.5	15	7.2	25
LSD - 5%	n.s.	n.s.	4.0	9	2.1	n.s.	7.6	8	n.s.	n.s.	2.1	7

E. Leaf Removal by Hand - Fremont.

The primary reason for doing this study was to obtain more definitive data on defoliation affects on yield and to compare these results with simulated hail which causes additional injury to fruits and shoots. Yield results are summarized in Table 12. These data indicated that generally 30% defoliation had no apparent influence on yield or maturation. Further, even 60% defoliation did not always result in yield reduction nor influence maturity; 90% defoliation did reduce yield and delay maturity and the greatest efforts occurred when the defoliation was done during bloom (fruit set) and during early fruit growth. Twin row culture tended to reduce the severity of yield reduction from 90% defoliation.

Table 12. Influence of Hard Leaf Removal on Yield of Single and Twin Row of Tomatoes, cv. H-1810 and H-7151, Fremont.

Yield - Tons/Acre of H-1810

Treatment (% defoliation)	Defoliation date =	Single Rows 6-2	6-16	7-2	7-21	Twin Rows 6-2	6-16	7-2	7-21
0		34.3	29.5	26.2	35.8	40.8	33.7	30.5	28.0
30		36.5	26.6	24.3	33.6	38.4	32.4	36.3	33.2
60		36.2	23.7	28.7	27.3	37.7	35.3	29.3	32.9
90		31.9	18.5	17.8	16.7	38.5	27.6	22.6	21.6
LSD - 5%					8.1				

Yield - Tons/Acre of H-7151

Treatment (% defoliation)	Defoliation date =	Single Rows 6-2	6-16	7-2	7-21	Twin Rows 6-2	6-16	7-2	7-21
0		31.2	28.0	22.9	28.7	33.0	30.5	25.7	34.2
30		30.9	26.0	26.4	22.8	33.6	31.0	27.0	26.2
60		31.9	18.8	19.6	24.4	33.1	25.3	25.2	23.3
90		29.2	15.8	10.9	12.5	31.2	19.3	13.7	16.4
LSD - 5%					6.2				

Summary:

Considerable progress was made on the objectives of this study. Detailed staging of plant development of processing tomatoes was not completed. It appears that the present cultivars including hybrids, grow and develop similarly and this plant type will likely persist for some time due to the necessity of concentrated fruit set and ripening for mechanical harvest. The plants do go through a vegetative stage which lasts from 6 to 8 weeks, a flowering and major fruit setting period which is about 2 weeks long and then a fruit

enlargement period which varies considerably with cultivar. The fruit ripening period follows and usually is 2-3 weeks in length.

Plant defoliation by hand did have an influence on yield but it required considerable defoliation to affect yield. It appears that type of injury sustained from hail is much more detrimental to yield than from defoliation alone. However, defoliation may be a good indication of severity of hail injury to the plant. Hail injury did cause yield reduction and/or delay in maturity, depending on stage of plant development when the injury occurred.

Needs for additional research include, 1) repeating and possibly expanding the trial on hail injury of different planting dates, 2) obtaining more detailed description of staging of plant development, 3) including twin row culture in studies, 4) determining influence of hail injury on split setting, 5) expanding the field-seeded section of this study because seeded plants grow and develop differently and may respond differently to hail injury than transplanted plants.

It must also be kept in mind that growing conditions vary from year to year and thus, results obtained in one year may not be the same the next year even though statistical odds suggest a high probability of similar results.

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